

AWWA

Wastewater Operator Field Guide



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AWWA Wastewater Operator Field Guide

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American Water Works
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Science and Technology

AWWA unites the drinking water community by developing and distributing authoritative scientific and technological knowledge. Through its members, AWWA develops industry standards for products and processes that advance public health and safety. AWWA also provides quality improvement programs for water and wastewater utilities.



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Preface

This guide is a compilation of information, charts, graphs, formulas, and definitions that are used by wastewater system operators in performing their daily duties. There is so much information contained in so many different sources that finding it while in the field can be a problem. This guide compiles information mostly from AWWA manuals, books, and standards, but also from other generic information found in many publications.

The sections of this guide group the information based on how it would be used by the operator. The guide includes information for both wastewater treatment and collection. Design engineers should also find this material helpful. Major sections include math, conversion factors, chemistry, safety, collection, pumps and motors, flow, wastewater treatment, biosolids, and disposal. Perusing the guide now will assist in finding handy information later. This is the first edition of the guide. If you would like to suggest changes or additions to the guide, please submit them to AWWA, Publishing Group, 6666 W. Quincy Ave., Denver, CO 80235.

Basic Math

A number of calculations are used in the operation of small wastewater facilities. Some only need to be calculated once and recorded for future reference; others may need to be calculated more frequently. Operators need to be familiar with the formulas and basic calculations to carry out their duties properly. Note that the formulas in this section are basic and general; specific formulas for particular components of wastewater systems can be found in the relevant sections of this guide.

SYSTÈME INTERNATIONAL UNITS

When performing calculations, water operators should pay particular attention not only to the numbers but also to the units involved. Where SI units and customary units are given, convert all units to one system, usually SI, *first*. Be sure to write the appropriate units with each number in the calculations for clarity. Inaccurate calculations and measurements can lead to incorrect reports and costly operational decisions. This section introduces the calculations that are the basic building blocks of the water/wastewater industry.

SI Prefixes

The SI is based on factors of ten, similar to the dollar. This allows the size of the unit of measurement to be increased or decreased while the base unit remains the same. The SI prefixes are

mega, M = $1,000,000 \times$ the base unit

kilo, k = $1,000 \times$ the base unit

hecta, h = $100 \times$ the base unit

deca, da = $10 \times$ the base unit

deci, d = $0.1 \times$ the base unit

centi, c = $0.01 \times$ the base unit

milli, m = $0.001 \times$ the base unit

micro, μ = $0.000001 \times$ the base unit

Base SI Units

Quantity	Unit	Abbreviation
length	meter	m
mass	kilogram	kg
time	second	sec
electric current	ampere	A
thermodynamic temperature	kelvin	K
amount of substance	mole	mol
luminous intensity	candela	cd

Supplementary SI Units

Quantity	Unit	Abbreviation
plane angle	radian	rad
solid angle	steradian	sr

Derived SI Units With Special Names

Quantity	Unit	Abbreviation	Equivalent-Units
			Abbreviation
frequency (of a periodic phenomenon)	hertz	Hz	sec^{-1}
force	newton	N	$\text{kg} \cdot \text{m}/\text{sec}^2$
pressure, stress	pascal	Pa	N/m^2
energy, work, quantity of heat	joule	J	$\text{N} \cdot \text{m}$
power, radiant flux	watt	W	J/sec
quantity of electricity, electric charge	coulomb	C	$\text{A} \cdot \text{sec}$
electric potential, potential difference, electromotive force	volt	V	W/A
electrical capacitance	farad	F	C/V
electrical resistance	ohm	Ω	V/A
electrical conductance	siemens	S	A/V
magnetic flux	weber	Wb	$\text{V} \cdot \text{sec}$
magnetic flux density	tesla	T	Wb/m^2
inductance	henry	H	Wb/A
luminous flux	lumen	lm	$\text{cd} \cdot \text{Sr}$
luminance	lux	lx	lm/m^2
activity (of a radionuclide)	becquerel	Bq	disintegrations/sec
absorbed ionizing radiation dose	gray	Gy	J/kg
ionizing radiation dose equivalent	sievert	Sv	J/kg

Some Common Derived SI Units

Quantity	Unit	Abbreviation
absorbed dose rate	grays per second	Gy/sec
acceleration	meters per second squared	m/sec ²
angular acceleration	radians per second squared	rad/sec ²
angular velocity	radians per second	rad/sec
area	square meter	m ²
concentration (amount of substance)	moles per cubic meter	mol/m ³
current density	amperes per square meter	A/m ²
density, mass	kilograms per cubic meter	kg/m ³
electric charge density	coulombs per cubic meter	C/m ³
electric field strength	volts per meter	V/m
electric flux density	coulombs per square meter	C/m ²
energy density	joules per cubic meter	J/m ³
entropy	joules per kelvin	J/K
exposure (X and gamma rays)	coulombs per kilogram	C/kg
heat capacity	joules per kelvin	J/K
heat flux density irradiance	watts per square meter	W/m ²
luminance	candelas per square meter	cd/m ²
magnetic field strength	amperes per meter	A/m
molar energy	joules per mole	J/mol
molar entropy	joules per mole kelvin	J/(mol·K)
molar heat capacity	joules per mole kelvin	J/(mol·K)
moment of force	newton-meter	N·m
permeability (magnetic)	henrys per meter	H/m
permittivity	farads per meter	F/m
power density	watts per square meter	W/m ²

Table continued on next page

Some Common Derived SI Units (continued)

Quantity	Unit	Abbreviation
radiance	watts per square meter steradian	$W/(m^2 \cdot sr)$
radiant intensity	watts per steradian	W/sr
specific energy	joules per kilogram	J/kg
specific entropy	joules per kilogram kelvin	J/(kg·K)
specific heat capacity	joules per kilogram kelvin	J/(kg·K)
specific volume	cubic meters per kilogram	m^3/kg
surface tension	newtons per meter	N/m
thermal conductivity	watts per meter kelvin	$W/(m \cdot K)$
velocity	meters per second	m/sec
viscosity, absolute	pascal-second	Pa·sec
viscosity, kinematic	square meters per second	m^2/sec
volume	cubic meter	m^3
wave number	per meter	m^{-1}

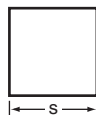
KEY FORMULAS FOR MATH

Area Formulas

Square

$$\text{area} = s \times s$$

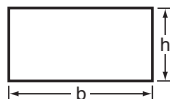
$$\text{diagonal} = 1.414 \times s$$



Rectangle or Parallelogram

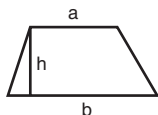
$$\text{area} = b \times h$$

$$\text{diagonal} = \text{square root } (b^2 + h^2)$$



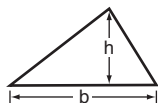
Trapezoid

$$\text{area} = \frac{(a + b)h}{2}$$



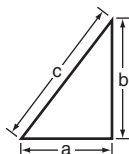
Any Triangle

$$\text{area} = \frac{b \times h}{2}$$



Right-Angle Triangle

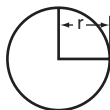
$$a^2 + b^2 = c^2$$



Circle

$$\text{area} = \pi \times r^2$$

$$\text{circumference} = 2 \times \pi \times r$$



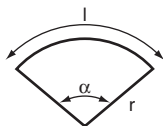
Sector of a Circle

$$\text{area} = \frac{\pi \times r \times r \times \alpha}{360}$$

$$\text{length} = 0.01745 \times r \times \alpha$$

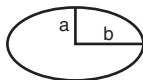
$$\text{angle} = \frac{1}{0.01745 \times r}$$

$$\text{radius} = \frac{1}{0.01745 \times \alpha}$$



Ellipse

$$\text{area} = \pi \times a \times b$$



Volume Formulas

$$\begin{aligned}\text{rectangle tank volume} &= \left(\begin{array}{c} \text{area of} \\ \text{rectangle} \end{array} \right) \left(\begin{array}{c} \text{third} \\ \text{dimension} \end{array} \right) \\ &= lw \left(\begin{array}{c} \text{area of} \\ \text{rectangle} \end{array} \right)\end{aligned}$$

$$\begin{aligned}\text{trough volume} &= \left(\begin{array}{c} \text{area of} \\ \text{rectangle} \end{array} \right) \left(\begin{array}{c} \text{third} \\ \text{dimension} \end{array} \right) \\ &= \left(\frac{bh}{2} \right) \left(\begin{array}{c} \text{third} \\ \text{dimension} \end{array} \right)\end{aligned}$$

$$\begin{aligned}\text{cylinder volume} &= \left(\begin{array}{c} \text{area of} \\ \text{rectangle} \end{array} \right) \left(\begin{array}{c} \text{third} \\ \text{dimension} \end{array} \right) \\ &= (0.785 D^2) \left(\begin{array}{c} \text{third} \\ \text{dimension} \end{array} \right)\end{aligned}$$

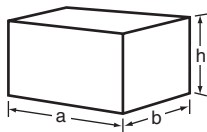
$$\text{cone volume} = \frac{1}{3} (\text{volume of a cylinder})$$

$$\text{sphere volume} = \left(\frac{\pi}{6} \right) (\text{diameter})^3$$

Rectangular Solid

$$\text{volume} = h \times a \times b$$

$$\text{surface area} = (2 \times a \times b) + (2 \times b \times h) + (2 \times a \times h)$$

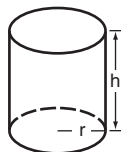


Cylinder

$$\text{volume} = \pi \times r^2 \times h$$

$$\text{surface area} = 2 \times \pi \times rh$$

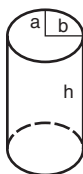
$$\pi = 3.142$$



Elliptical Cylinder

$$\text{volume} = \pi \times a \times b \times h$$

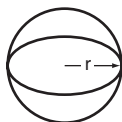
$$\text{area} = 6.283 \times \frac{\sqrt{a^2 + b^2}}{2} \times h + 6.283 \times a \times b$$



Sphere

$$\text{volume} = \frac{4 \times \pi \times r^3}{3}$$

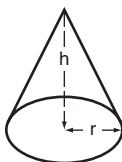
$$\text{surface area} = 4 \times \pi \times r^2$$



Cone

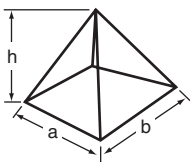
$$\text{volume} = \frac{\pi \times r^2 \times h}{3}$$

$$\text{surface area} = \pi \times r \times \sqrt{r^2 + h^2} + \pi \times r^2$$



Pyramid

$$\text{volume} = \frac{a \times b \times h}{3}$$



Other Formulas

$$\begin{aligned} \frac{\text{theoretical water}}{\text{horsepower}} &= \frac{\text{gal/min} \times \text{total head, ft}}{3,960} \\ &= \frac{\text{gal/min} \times \text{lb/in.}^2}{1,715} \end{aligned}$$

$$\text{brake horsepower} = \frac{\text{theoretical water horsepower}}{\text{pump efficiency}}$$

$$\text{detention time, min} = \frac{\text{volume of basin, gal}}{\text{flow rate, gpm}}$$



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$$\text{filter backwash rate, gal/min/ft}^2 = \frac{\text{flow, gpm}}{\text{area of filter, ft}^2}$$

$$\text{surface overflow rate} = \frac{\text{flow, gpm}}{\text{area, ft}^2}$$

$$\text{weir overflow rate} = \frac{\text{flow, gpm}}{\text{weir length, ft}}$$

$$\text{pounds per mil gal} = \text{parts per million} \times 8.34$$

$$\text{parts per million} = \text{pounds per mil gal} \times 0.12$$

$$\text{parts per million} = \text{percent strength of solution} \times 10,000$$

$$\text{pounds per day} = \text{volume, mgd} \times \text{dosage, mg/L} \times 8.34 \text{ lb/gal}$$

$$\text{dosage, mg/L} = \frac{\text{feed, lb/day}}{\text{volume, mgd} \times 8.34 \text{ lb/gal}}$$

$$\text{percent element by weight} = \frac{\text{weight of element in compound}}{\text{molecular weight of compound}} \times 100$$

$$\text{rectangular basin volume, ft}^3 = \text{length, ft} \times \text{width, ft} \times \text{height, ft}$$

$$\text{rectangular basin volume, gal} = \text{length, ft} \times \text{width, ft} \times \text{height, ft} \times 7.48 \text{ gal/ft}^3$$

$$\text{right cylinder volume, ft}^3 = 0.785 \times \text{diameter}^2, \text{ ft} \times \text{height or depth, ft}$$

$$\text{right cylinder volume, gal} = \frac{0.785 \times \text{diameter}^2, \text{ ft} \times \text{height or depth, ft}}{\text{ft} \times 7.48 \text{ gal/ft}^3}$$

$$\text{gallons per capita per day, average water usage} = \frac{\text{volume, gpd}}{\text{population served/day}}$$

$$\text{supply, days (full to tank dry)} = \frac{\text{volume, gpd}}{\text{population served} \times \text{gpcd}}$$

$$\begin{aligned} \text{gallons per day of} \\ \text{water consumption, (demand/day)} &= \text{population} \times \text{gpcd} \end{aligned}$$

Consumption Averages, per capita

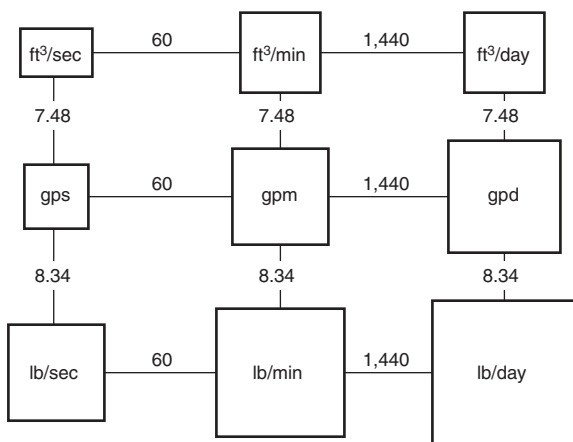
winter = 170 gpcd

spring = 225 gpcd

summer = 325 gpcd

KEY CONVERSIONS FOR FLOWS

Conversion of US customary flow units can be easily made using the block diagram below. When moving from a smaller to a larger block, multiply by the factor shown on the connecting line. When moving from a larger to a smaller block, divide.



$$\text{flow, gpm} = \text{flow, cfs} \times 448.8 \text{ gpm/cfs}$$

$$\text{flow, cfs} = \frac{\text{flow, gpm}}{448.8 \text{ gpm/cfs}}$$

$$\text{pipe diameter, in.} = \frac{\text{area, ft}^2}{0.785} \times 12 \text{ in./ft}$$

$$\text{actual leakage, gpd/mi./in.} = \frac{\text{leak rate, gpd}}{\text{length, mi.} \times \text{diameter, in.}}$$

NOTE: minimum flushing velocity: 2.5 fps

maximum pipe velocity: 5.0 fps

key conversions: 1.55 cfs/mgd; 448.8 gpm/cfs

KEY FORMULAS FOR FLOWS AND METERS

Velocity

$$\text{flow, cfs} = \text{area, ft} \times \text{velocity, fps}$$

$$\frac{\text{gpm}}{448.8 \text{ gpm/cfs}} = 0.785 \times \text{diameter, ft}^2 \times \frac{\text{distance, ft}}{\text{time, sec}}$$

$$\text{velocity, fps} = \frac{\text{flow, cfs}}{\text{area, ft}^2}$$

$$\text{area, ft}^2 = \frac{\text{flow, cfs}}{\text{velocity, fps}}$$

Head Loss Resulting From Friction

Darcy-Weisbach Formula

$$h_L = f(L/D)(V^2/2g)$$

Where (in any consistent set of units):

h_L = head loss

f = friction factor, dimensionless

L = length of pipe

D = diameter of the pipe

V = average velocity

g = gravity constant

Flow Rate Calculations

The *rule of continuity* states that the flow Q that enters a system must also be the flow that leaves the system.

$$Q_1 = Q_2 \quad \text{or} \quad A_1 V_1 = A_2 V_2$$

or

$$Q = AV$$

Where:

Q = flow rate

A = area

V = velocity

$$\begin{aligned} Q &= A \times V \\ \left(\begin{array}{c} \text{flow rate,} \\ \text{ft}^3/\text{time} \end{array} \right) &= \left(\begin{array}{c} \text{width,} \\ \text{ft} \end{array} \right) \times \left(\begin{array}{c} \text{depth,} \\ \text{ft} \end{array} \right) \times \left(\begin{array}{c} \text{velocity,} \\ \text{ft/time} \end{array} \right) \\ \left(\begin{array}{c} \text{feed rate,} \\ \text{lb/day} \end{array} \right) &= \left(\begin{array}{c} \text{dosage,} \\ \text{ppm} \end{array} \right) \times \left(\begin{array}{c} \text{flow rate,} \\ \text{mgd} \end{array} \right) \times \left(\begin{array}{c} \text{conversion factor} \\ 8.34 \text{ lb/gal} \end{array} \right) \\ \left(\begin{array}{c} \text{chlorine} \\ \text{weight, lb} \end{array} \right) &= \left(\begin{array}{c} \text{dosage,} \\ \text{mg/L} \end{array} \right) \times \left(\begin{array}{c} \text{volume of} \\ \text{container} \\ \text{mil/gal} \end{array} \right) \times \left(\begin{array}{c} \text{conversion factor} \\ 8.34 \text{ lb/gal} \end{array} \right) \end{aligned}$$

Summary of Pressure Requirements

Requirement	Value		Location
	psi	(kPa)	
Minimum pressure	35	(241)	All points within distribution system
	20	(140)	All ground level points
Desired maximum	100	(690)	All points within distribution system
Fire flow minimum	20	(140)	All points within distribution system
Ideal range	50–75	(345–417)	Residences
	35–60	(241–414)	All points within distribution system

Units of Measure and Conversions

The ability to accurately and consistently measure such variables as flow and head, along with wastewater quality indicators such as chemical and biological oxygen demand, total suspended solids, toxins, and pathogens is a key component of the successful operation of a wastewater distribution system. This section provides the most common units of measure and associated conversions typically used in the wastewater industry.

UNITS OF MEASURE

acre An SI unit of area.

acre-foot (acre-ft) A unit of volume. One acre-foot is the equivalent amount or volume of water covering an area of 1 acre that is 1 foot deep.

ampere (A) An SI unit of constant current that, if maintained in two straight parallel conductors of infinite length or negligible cross section and placed 1 meter apart in a vacuum, would produce a force equal to 2×10^{-7} newtons per meter of length.

ampere-hour (A·hr) A unit of electric charge equal to 1 ampere flowing for 1 hour.

angstrom (Å) A unit of length equal to 10^{-10} meter.

atmosphere (atm) A unit of pressure equal to 14.7 pounds per square inch (101.3 kilopascals) at average sea level under standard conditions.

bar A unit of pressure defined as 100 kilopascals.

barrel (bbl) A unit of volume, frequently 42 gallons for petroleum or 55 gallons for water.

baud A measure of analog data transmission speed that describes the modulation rate of a wave, or the average frequency of the signal. One baud equals 1 signal unit per second. If an analog signal is viewed as an electromagnetic wave, one complete wavelength or cycle is equivalent to a signal unit. The term *baud* has often been used synonymously with *bits per second*. The baud rate may equal bits per second for some transmission techniques, but special modulation techniques frequently deliver a bits-per-second rate higher than the baud rate.

becquerel (Bq) An SI unit of the activity of a radionuclide decaying at the rate of one spontaneous nuclear transition per second.

billion electron volts (BeV) A unit of energy equivalent to 10^9 electron volts.

billion gallons per day (bgd) A unit for expressing the volumetric flow rate of water being pumped, distributed, or used.

binary digits (bits) per second (bps) A measure of the data transmission rate. A binary digit is the smallest unit of information or data, represented by a binary “1” or “0.”

British thermal unit (Btu) A unit of energy. One British thermal unit was formerly defined as the quantity of heat required to raise the temperature of 1 pound of pure water 1° Fahrenheit; now defined as 1,055.06 joules.

bushel (bu) A unit of volume.

caliber (1) The diameter of a round body, especially the internal diameter of a hollow cylinder. (2) The diameter of a bullet or other projectile.



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or the diameter of a gun's bore. In US customary units, usually expressed in hundredths or thousandths of an inch and typically written as a decimal fraction (e.g., 0.32). In SI units, expressed in millimeters.

calorie (gram calorie) A unit of energy. One calorie is the amount of heat necessary to raise the temperature of 1 gram of pure water at 15° Celsius by 1° Celsius.

candela (cd) An SI unit of luminous intensity. One candela is the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540×10^{12} hertz and that has a radiant intensity in that direction of $1/683$ watt per steradian.

candle A unit of light intensity. One candle is equal to 1 candela. Candelas are the preferred units.

candlepower A unit of light intensity. One candlepower is equal to 1 candela. Candelas are the preferred units.

centimeter (cm) A unit of length defined as one hundredth of a meter.

centipoise A unit of absolute viscosity equivalent to 10^{-2} poise. See also *poise*.

chloroplatinate (Co-Pt) unit (cpu) See *color unit*.

cobalt-platinum unit See *color unit*.

colony-forming unit (cfu) A unit of expression used in enumerating bacteria by plate-counting methods. A colony of bacteria develops from a single cell or a group of cells, either of which is a colony-forming unit.

color unit (cu) The unit used to report the color of water. Standard solutions of color are prepared from potassium chloroplatinate (K_2PtCl_6) and cobaltous chloride ($CoCl_2 \cdot 6H_2O$). Adding the following amounts in 1,000 milliliters of distilled water produces a solution with a color of 500 color units: 1.246 grams potassium chloroplatinate, 1.00 grams geobaltous chloride, and 100 milliliters concentrated hydrochloric acid (HCl).

coulomb (C) An SI unit of a quantity of electricity or electric charge. One coulomb is the quantity of electricity transported in 1 second by a current of 1 ampere, or about 6.25×10^{18} electrons. Coulombs are equivalent to ampere-seconds.

coulombs per kilogram (C/kg) A unit of exposure dose of ionizing radiation. See also *roentgen*.

cubic feet (ft³) A unit of volume equivalent to a cube with a dimension of 1 foot on each side.

cubic feet per hour (ft³/hr) A unit for indicating the rate of liquid flow past a given point.

cubic feet per minute (ft³/min, CFM) A unit for indicating the rate of liquid flow past a given point.

cubic feet per second (ft³/sec, cfs) A unit for indicating the rate of liquid flow past a given point.

cubic inch (in.³) A unit of volume equivalent to a cube with a dimension of 1 inch on each side.

cubic meter (m³) A unit of volume equivalent to a cube with a dimension of 1 meter on each side.

cubic yard (yd³) A unit of volume equivalent to a cube with a dimension of 1 yard on each side.

curie (Ci) A unit of radioactivity. One curie equals 37 billion disintegrations per second, or approximately the radioactivity of 1 gram of radium.

cycles per second (cps) A unit for expressing the number of times something fluctuates, vibrates, or oscillates each second. These units have been replaced by hertz. One hertz equals 1 cycle per second.

dalton (D) A unit of weight. One dalton designates $1/16$ the weight of oxygen-16. One dalton is equivalent to 0.9997 atomic weight unit, or nominally 1 atomic weight unit.

darcy (da) The unit used to describe the permeability of a porous medium (e.g., the movement of fluids through underground formations studied by petroleum engineers, geologists or geophysicists, and groundwater specialists). A porous medium is said to have a permeability of 1 darcy if a fluid of 1-centipoise viscosity that completely fills the pore space of the medium will flow through it at a rate of 1 cubic centimeter per second per square centimeter of cross-sectional area under a pressure gradient of 1 atmosphere per centimeter of length. In SI units, 1 darcy = 9.87×10^{-13} square meters.

day A unit of time equal to 24 hours.

decibel (dB) A dimensionless ratio of two values expressed in the same units of measure. It is most often applied to a power ratio and defined as decibels = $10 \log_{10}$ (actual power level/reference power level), or $\text{dB} = 10 \log_{10} (W_2/W_1)$, where W is the power level in watts per square centimeter for sound. Power is proportional to the square of potential. In the case of sound, the potential is measured as a pressure, but the sound level is an energy level. Thus, $\text{dB} = 10 \log_{10} (p_2/p_1)^2$ or $\text{dB} = 20 \log_{10} (p_2/p_1)$, where p is the potential. The reference levels are not well standardized. For example, sound power is usually measured above 10^{-12} watts per square centimeter, but both 10^{-11} and 10^{-16} watts per square centimeter are used. Sound pressure is usually measured above 20 micropascals in

air. The reference level is not important in most cases because one is usually concerned with the difference in levels, i.e., with a power ratio. A power ratio of 1.26 produces a difference of 1 decibel.

deciliter (dL) A unit of volume defined as one tenth of a liter. This unit is often used to express concentration in clinical chemistry. For example, a concentration of lead in blood would typically be reported in units of micrograms per deciliter.

degree (°) A measure of the phase angle in a periodic electrical wave. One degree is $1/360$ of the complete cycle of the periodic wave. Three hundred sixty degrees equals 2π radians.

degree Celsius (°C) A unit of temperature. The degree Celsius is exactly equal to the kelvin and is used in place of the kelvin for expressing Celsius temperature (symbol t) defined by the equation $t = T - T_0$, where T is the thermodynamic temperature in kelvin and $T_0 = 273.15$ kelvin by definition.

degree Fahrenheit (°F) A unit of temperature on a scale in which 32° marks the freezing point and 212° the boiling point of water at a barometric pressure of 14.7 pounds per square inch.

degree kelvin (K) See kelvin.

dram (dr) Small weight. Two different drams exist: the apothecary's dram (equivalent to $1/3.54$ gram) and the avoirdupois dram (equivalent to $1/1.17$ gram).

electron volt (eV) A unit of energy commonly used in the fields of nuclear and high-energy physics. One electron volt is the energy transferred to a charged particle with a single charge when that particle falls through a potential of 1 volt. An electron volt is equal to 1.6×10^{-19} joule.

equivalents per liter (eq/L) An SI unit of an expression of concentration equivalent to normality. The normality of a solution (equivalent weights per liter) is a convenient way of expressing concentration in volumetric analyses.

fathom A unit of length equivalent to 6 feet, used primarily in marine measurements.

feet (ft) The plural form of a unit of length (the singular form is *foot*).

feet board measure (fbm) A unit of volume. One board foot is represented by a board measuring 1 foot long by 1 foot wide by 1 inch thick (144 cubic inches). A board measuring 0.5 feet by 2 feet by 2 inches thick would equal 2 board feet.

feet per hour (ft/hr) A unit for expressing the rate of movement.

feet per minute (ft/min) A unit for expressing the rate of movement.

feet per second (ft/sec, fps) A unit for expressing the rate of movement.

feet per second squared (ft/sec²) A unit of acceleration (the rate of change of linear motion). For example, the acceleration caused by gravity is 32.2 ft/sec² at sea level.

feet squared per second (ft²/sec) A unit used in flux calculations.

fluid ounce (fl oz) A unit for expressing volume, equivalent to 1/128 of a gallon.

foot A unit of length, equivalent to 12 inches. See also *US customary system of units*.

foot of water (39.2° Fahrenheit) A unit for expressing pressure or elevation head.

foot per second per foot (ft/sec/ft; sec⁻¹) A unit for expressing velocity gradient.

foot-pound, torque A unit for expressing the energy used in imparting rotation, often associated with the power of engine-driven mechanisms.

foot-pound, work A unit of measure of the transference of energy when a force produces movement of an object.

formazin turbidity unit (ftu) A turbidity unit appropriate when a chemical solution of formazin is used as a standard to calibrate a turbidimeter. If a nephelometric turbidimeter is used, nephelometric turbidity units and formazin turbidity units are equivalent. See also *nephelometric turbidity unit*.

gallon (gal) A unit of volume, equivalent to 231 cubic inches. See also *Imperial gallon*.

gallons per capita per day (gpcd) A unit typically used to express the average number of gallons of water used by the average person each day in a water system. The calculation is made by dividing the total gallons of water used each day by the total number of people using the water system.

gallons per day (gpd) A unit for expressing the discharge or flow past a fixed point.

gallons per day per square foot (gpd/ft², gsfd) A unit of flux equal to the quantity of liquid in gallons per day through 1 square foot of area. It may also be expressed as a velocity in units of length per unit time. In pressure-driven membrane treatment processes, this unit is commonly used to describe the volumetric flow rate of permeate through a unit area of active membrane surface. In settling tanks, this rate is called the overflow rate.

gallons per flush (gal/flush) The number of gallons used with each flush of a toilet.

gallons per hour (gph) A unit for expressing the discharge or flow of a liquid past a fixed point.

gallons per minute (gpm) A unit for expressing the discharge or flow of a liquid past a fixed point.

gallons per minute per square foot (gpm/ft²) A unit for expressing flux, the discharge or flow of a liquid through a unit of area. In a filtration process, this unit is commonly used to describe the volumetric flow rate of filtrate through a unit of filter media surface area. It may also be expressed as a velocity in units of length per unit time.

gallons per second (gps) A unit for expressing the discharge or flow past a fixed point.

gallons per square foot (gal/ft²) A unit for expressing flux, the discharge or flow of a liquid through each unit of surface area of a granular filter during a filter run (between cleaning or backwashing).

gallons per square foot per day See *gallons per day per square foot*.

gallons per year (gpy) A unit for expressing the discharge or flow of a liquid past a fixed point.

gamma (γ) A symbol used to represent 1 microgram. Avoid using this symbol; the preferred symbol is μg.

gigabyte (GB) A unit of computer memory. One gigabyte equals 1 megabyte times 1 kilobyte, or 1,073,741,824 bytes (roughly 1 billion bytes).

gigaliter (GL) A unit of volume defined as 1 billion liters.

grad A unit of angular measure equal to 1/400 of a circle.

grain (gr) A unit of weight.

grains per gallon (gpg) A unit sometimes used for reporting water analysis concentration results in the United States and Canada.

gram (g) A fractional unit of mass. One gram was originally defined as the weight of 1 cubic centimeter or 1 milliliter of water at 4° Celsius. Now it is 1/1,000 of the mass of a certain block of platinum-iridium alloy known as the international prototype kilogram, preserved at Sèvres, France.

gram molecular weight The molecular weight of a compound in grams. For example, the gram molecular weight of CO₂ is 44.01 grams. See also *mole*.

gray (Gy) An SI unit of *absorbed* ionizing radiation dose. One gray, equal to 100 rad, is the absorbed dose when the energy per unit mass imparted to matter by ionizing radiation is 1 joule per kilogram. See also *rad*; *rem*; *sievert*.

hectare (ha) A unit of area equivalent to 10,000 square meters.

henry (H) An SI unit of electric inductance, equivalent to meters squared kilograms per second squared per ampere squared. One henry is the inductance of a closed circuit in which an electromotive force of 1 volt is produced when the electric current in the circuit varies uniformly at a rate of 1 ampere per second.

hertz (Hz) An SI unit of measure of the frequency of a periodic phenomenon in which the period is 1 second, equivalent to second^{-1} . Hertz units were formerly expressed as cycles per second.

horsepower (hp) A standard unit of power. See also *US customary system of units*.

horsepower-hour (hp·hr) A unit of energy or work.

hour (hr) An interval of time equal to $1/24$ of a day.

Imperial gallon A unit of volume used in the United Kingdom, equivalent to the volume of 10 pounds of freshwater.

inch (in.) A unit of length.

inch of mercury (32° Fahrenheit) A unit of pressure or elevation head.

inch-pound (in.-lb) A unit of energy or torque.

inches per minute (in./min) A unit of velocity.

inches per second (in./sec) A unit of velocity.

International System of Units. See *Système International*.

joule (J) An SI unit for energy, work, or quantity of heat, equivalent to meters squared kilograms per second squared. One joule is the work done when the point of application of a force of 1 newton is displaced a distance of 1 meter in the direction of the force (1 newton-meter).

kelvin (K) An SI unit of thermodynamic temperature. No degree sign (°) is used. Zero kelvin is absolute zero, the complete absence of heat.

kilo A prefix meaning 1,000.

kilobyte (kB) A unit of measurement for digital storage of data in various computer media, such as hard disks, random access memory, and compact discs. One kilobyte is 1,024 bytes.

kilogram A unit of weight equivalent to 1,000 grains.

kilogram (kg) An SI unit of mass. One kilogram is equal to the mass of a certain block of platinum-iridium alloy known as the international prototype kilogram (nicknamed Le Grand K), preserved at Sèvres, France. A new standard is expected early in the 21st century.

kilohertz (kHz) A unit of frequency equal to 1,000 hertz or 1,000 cycles per second.

kiloliter A unit of volume equal to 1,000 liters or 1 cubic meter.

kilopascal (kPa) A unit of pressure equal to 1,000 pascals.

kiloreactive volt-ampere (kvar) A unit of reactive power equal to 1,000 volt-ampere-reactive.

kilovolt (kV) A unit of electrical potential equal to 1,000 volts.

kilovolt-ampere (kVA) A unit of electrical power equal to 1,000 volt-amperes.

kilowatt (kW) A unit of electrical power equal to 1,000 watts.

kilowatt-hour (kW·hr) A unit of energy or work.

lambda (λ) A symbol used to represent 1 microliter. Avoid using this symbol; the preferred symbol is μL .

linear feet (lin ft) A unit of distance in feet along an object.

liter (L) A unit of volume. One liter of pure water weighs 1,000 grams at 4° Celsius at 1 atmosphere of pressure.

liters per day (L/day) A unit for expressing a volumetric flow rate past a given point.

liters per minute (L/min) A unit for expressing a volumetric flow rate past a given point.

lumen (lm) An SI unit of luminous flux equivalent to candela-steradian. One lumen is the luminous flux emitted in a solid angle of 1 steradian by a point source having a uniform intensity of 1 candela.

lux (lx) An SI unit of illuminance. One lux is the illuminance intensity given by a luminous flux of 1 lumen uniformly distributed over a surface of 1 square meter. One lux is equivalent to 1 candela-steradian per meter squared.

mega Prefix meaning 10^6 in Système International.

megabyte (MB) A unit of computer memory storage equivalent to 1,048,576 bytes.

megahertz (mHz) A unit of frequency equal to 1 million hertz, or 1 million cycles per second.

megaliter (ML) A unit of volume equal to 1 million liters.

megaohm (megohm) A unit of electrical resistance equal to 1 million ohms. This is the unit of measurement for testing the electrical resistance of water to determine its purity. The closer water comes to absolute purity, the greater its resistance to conducting an electric current. Absolutely pure water has a specific resistance of more than 18 million ohms across 1 centimeter at a temperature of 25° Celsius. See also *ohm*.

meter (m) An SI unit of length. One meter is the length of the path traveled by light in a vacuum during a time interval of 1/299,792,458 second.

meters per second per meter (m/sec/m; sec^{-1}) A unit for expressing velocity gradient.

metric system A system of units based on three basic units: the meter for length, the kilogram for mass, and the second for time—the so-called MKS system. Decimal fractions and multiples of the basic units are used for larger and smaller quantities. The principal departure of the SI from the more familiar form of metric engineering units is the use of the newton as the unit of force instead of kilogram-force. Likewise, the newton instead of kilogram-force is used in combination units including force; for example, pressure or stress (newton per square meter), energy (newton-meter = joule), and power (newton-meter per second = watt). See also *Système International*.

metric ton (t) A unit of weight equal to 1,000 kilograms.

mho A unit of electrical conductivity in US customary units equal to 1 siemens, which is an SI unit. See also *siemens*.

microgram (μg) A unit of mass equal to one millionth of a gram.

micrograms per liter ($\mu\text{g/L}$) A unit of concentration for dissolved substances based on their weights.

microhm A unit of electrical resistance equal to one millionth of an ohm.

micrometer (μm) A unit of length equal to one millionth of a meter.

micromho A unit of electrical conductivity equal to one millionth of an mho. See also *microsiemens*.

micromhos per centimeter ($\mu\text{mho/cm}$) A measure of the conductivity of a water sample, equivalent to microsiemens per centimeter. Absolutely pure water, from a mineral content standpoint, has a conductivity of 0.055 micromhos per centimeter at 25° Celsius.

micromolar (μM) A concentration in which the molecular weight of a substance (in grams) divided by 10^6 (i.e., 1 μmol) is dissolved in enough solvent to make 1 liter of solution. See also *micromole*; *molar*.

micromole (μmol) A unit of weight for a chemical substance, equal to one millionth of a mole. See also *mole*.

micron (μ) A unit of length equal to 1 micrometer. Micrometers are the preferred units.

microsiemens (μS) A unit of conductivity equal to one millionth of a siemens. The microsiemens is the practical unit of measurement for conductivity and is used to approximate the total dissolved solids content of water. Water with 100 milligrams per liter of sodium chloride (NaCl) will have a specific resistance of 4,716 ohm-centimeters and a conductance of 212 microsiemens per centimeter. Absolutely pure water, from a mineral content standpoint, has a conductivity of 0.055 microsiemens per centimeter at 25° Celsius.

microwatt (μW) A unit of power equal to one millionth of a watt.

microwatt-seconds per square centimeter ($\mu\text{W-sec/cm}^2$) A unit of measurement of irradiation intensity and retention or contact time in the operation of ultraviolet systems.

mil A unit of length equal to one thousandth of an inch.

mile (mi) A unit of length, equivalent to 5,280 feet.

miles per hour (mph) A unit of speed.

milliamperere (mA) A unit of electrical current equal to one thousandth of an ampere.

milliequivalent (meq) A unit of weight equal to one thousandth the equivalent weight of a chemical.

milliequivalents per liter (meq/L) A unit of concentration for dissolved substances based on their equivalent weights.

milligram (mg) A unit of mass equal to one thousandth of a gram.

milligrams per liter (mg/L) The unit used in reporting the concentration of matter in water as determined by water analyses.

milliliter (mL) A unit of volume equal to one thousandth of a liter.

millimeter (mm) A unit of length equal to one thousandth of a meter.

millimicron ($\mu\mu$) A unit of length equal to one thousandth of a micron.

This unit is correctly called a nanometer.

millimolar (mM) A concentration in which the molecular weight of a substance (in grams) divided by 10^3 (i.e., 1 mmol) is dissolved in enough solvent to make 1 liter of solution. See also *millimole*; *molar*.

millimole (mmol) A unit of weight for a chemical substance, equal to one-thousandth of a mole. See also *mole*.

million electron volts (MeV) A unit of energy equal to 10^6 electron volts. This unit is commonly used in the fields of nuclear and high-energy physics. See also *electron volt*.

million gallons (mil gal, MG) A unit of volume equal to 10^6 .

million gallons per day (mgd) A unit for expressing the flow rate past a given point.

mils per year (mpy) A unit for expressing the loss of metal resulting from corrosion. Assuming the corrosion process is uniformly distributed over the test surface, the corrosion rate of a metal coupon may be converted to a penetration rate (length per time) by dividing the unit area of metal loss by the metal density (mass per volume). The penetration rate, expressed as mils per year, describes the rate at which the metal surface is receding because of the corrosion-induced metal loss. See also *mil*.

minute (min) A unit of time equal to 60 seconds.

molar (M) A unit for expressing the molarity of a solution. A 1-molar solution consists of 1 gram molecular weight of a compound dissolved in

enough water to make 1 liter of solution. A gram molecular weight is the molecular weight of a compound in grams. For example, the molecular weight of sulfuric acid (H_2SO_4) is 98. A 1-molar, or 1-mole-per-liter, solution of sulfuric acid would consist of 98 grams of H_2SO_4 dissolved in enough distilled water to make 1 liter of solution.

mole (mol) A mole of a substance is a number of grams of that substance where the number equals the substance's molecular weight.

moles per liter (mol/L, M) A unit of concentration for a dissolved substance.

mrem An expression or measure of the extent of biological injury that would result from the absorption of a particular radionuclide at a given dosage over 1 year.

nanograms per liter (ng/L) A unit expressing the concentration of chemical constituents in solution as mass (nanograms) of solute per unit volume (liter) of water. One million nanograms per liter is equivalent to 1 milligram per liter.

nanometer (nm) A unit of length defined as 10^{-12} meter.

nephelometric turbidity unit (ntu) A unit for expressing the cloudiness (turbidity) of a sample as measured by a nephelometric turbidimeter. A turbidity of 1 nephelometric turbidity unit is equivalent to the turbidity created by a 1:4,000 dilution of a stock solution of 5.0 milliliters of a 1.000-gram hydrazine sulfate ($(\text{NH}_2)_2 \cdot \text{H}_2\text{SO}_4$) in 100 milliliters of distilled water solution plus 5.0 milliliters of a 10.00-gram hexamethylene-tetramine ($(\text{CH}_2)_6\text{N}_4$) in 100 milliliters of distilled water solution that has stood for 24 hours at $25 \pm 3^\circ$ Celsius.

newton (N) An SI unit of force. One newton is equivalent to 1 kilogram-meter per second squared. It is the force, when applied to a body having a mass of 1 kilogram, that gives the body an acceleration of 1 meter per second squared. The newton replaces the unit kilogram-force, which is the unit of force in the metric system.

ohm (Ω) An SI unit of electrical resistance, equivalent to meters squared kilograms per second cubed per ampere squared. One ohm is the electrical resistance between two points of a conductor when a constant difference of 1 volt potential applied between the two points produces in the conductor a current of 1 ampere, with the conductor not being the source of any electromotive force.

one hundred cubic feet (ccf) A unit of volume.

ounce (oz) A unit of force, mass, and volume.

ounce-inch (ounce-in., ozf-in.) A unit of torque.

parts per billion (ppb) A unit of proportion, equal to 10^{-9} . This expression represents a measure of the concentration of a substance dissolved in water on a weight-per-weight basis or the concentration of a substance in air on a weight-per-volume basis. One liter of water at 4° Celsius has a mass equal to 1.000 kilogram (specific gravity equal to 1.000, or 1 billion micrograms). Thus, when 1 microgram of a substance is dissolved in 1 liter of water with a specific gravity of 1.000 (1 microgram per liter), this would be one part of substance per billion parts of water on a weight-per-weight basis. This terminology is now obsolete, and the term *micrograms per liter* ($\mu\text{g/L}$) should be used for concentrations in water.

parts per million (ppm) A unit of proportion, equal to 10^{-6} . This terminology is now obsolete, and the term *milligrams per liter* (mg/L) should be used for concentrations in water. See also *parts per billion*.

parts per thousand (ppt) A unit of proportion, equal to 10^{-3} . This terminology is now obsolete, and the term *grams per liter* (g/L) should be used for concentrations in water. See also *parts per billion*.

parts per trillion (ppt) A unit of proportion, equal to 10^{-12} . This terminology is now obsolete, and the term *nanograms per liter* (ng/L) should be used for concentrations in water. See also *parts per billion*.

pascal (Pa) An SI unit of pressure or stress equivalent to newtons per meter per second squared. One pascal is the pressure or stress of 1 newton per square meter.

pascal-second (Pa·sec) A unit of absolute viscosity equivalent to kilogram per second per meter cubed. The viscosity of pure water at 20° Celsius is 0.0010087 pascal-second.

pi (π) The ratio of the circumference of a circle to the diameter of that circle, approximately equal to 3.14159 (or about $22/7$).

picocurie (pCi) A unit of radioactivity. One picocurie represents a quantity of radioactive material with an activity equal to one millionth of one millionth of a curie (i.e., 10^{-12} curie).

picocuries per liter (pCi/L) A radioactivity concentration unit.

picogram (pg) A unit of mass equal to 10^{-12} gram or 10^{-15} kilogram.

picosecond (ps) A unit of time equal to one trillionth (10^{-12}) of a second.

plaque-forming unit (pfu) A unit expressing the number of infectious virus particles. One plaque-forming unit is equivalent to one virus particle.

platinum-cobalt (Pt-Co) color unit (PCU) See *color unit*.

poise A unit of absolute viscosity, equivalent to 1 gram mass per centimeter per second.

pound (lb) A unit used to represent either a mass or a force. This can be a confusing unit because two terms actually exist, *pound mass* (lbm) and *pound force* (lbf). One pound force is the force with which a 1-pound mass is attracted to the earth. In equation form,

$$\text{pounds force} = \frac{\text{(pounds mass)} \left(\frac{\text{local acceleration resulting from gravity}}{\text{standard acceleration resulting from gravity}} \right)}{1}$$

One pound mass, on the other hand, is the mass that will accelerate at 32.2 feet per second squared when a 1-pound force is applied to it. As an example of the effect of the local acceleration resulting from gravity, at 10,000 feet (3,300 meters) above sea level, where the acceleration resulting from gravity is 32.17 feet per second squared (979.6 centimeters per second squared) instead of the sea level value of 32.2 feet per second squared (980.6 centimeters per second squared), the force of gravity on a 1-pound mass would be 0.999 pounds force. On the surface of the earth at sea level, pound mass and pound force are numerically the same because the acceleration resulting from gravity is applied to an object, although they are quite different physical quantities. This may lead to confusion.

pound force (lbf) See *pound*.

pound mass (lbm) See *pound*.

pounds per day (lb/day) A unit for expressing the rate at which a chemical is added to a water treatment process.

pounds per square foot (lb/ft²) A unit of pressure.

pounds per square inch (psi) A unit of pressure.

pounds per square inch absolute (psia) A unit of pressure reflecting the sum of gauge pressure and atmospheric pressure.

pounds per square inch gauge (psig) A unit of pressure reflecting the pressure measured with respect to that of the atmosphere. The gauge is adjusted to read zero at the surrounding atmospheric pressure.

rad (radiation absorbed dose) A unit of adsorbed dose of ionizing radiation. Exposure of soft tissue or similar material to 1 roentgen results in the absorption of about 100 ergs (10^{-5} joules) of energy per gram, which is 1 rad. See also *gray*; *rem*; *sievert*.

radian (rad) An SI unit of measure of a plane angle that is equal to the angle at the center of a circle subtended by an arc equal in length to the radius. This unit is also used to measure the phase angle in a periodic electrical wave. Note that 2π radians is equivalent to 360° .

radians per second (rad/sec) A unit of angular frequency.

rem (roentgen equivalent man [person]) A unit of equivalent dose of ionizing radiation, developed by the International Commission on Radiation Units and Measurements in 1962 to reflect the finding that the biological effects of ionizing radiation were dependent on the nature of the radiation as well as other factors. For X- and gamma radiation, the weighting factor is 1; thus, 1 rad equals 1 rem. For alpha radiation, however, 1 rad equals 20 rem. See also *gray*; *rad*; *sievert*.

revolutions per minute (rpm) A unit for expressing the frequency of rotation, or the number of times a fixed point revolves around its axis in 1 minute.

revolutions per second (rps) A unit for expressing the frequency of rotation, or the number of times a fixed point revolves around its axis in 1 second.

roentgen (r) The quantity of electrical charge produced by X- or gamma radiation. One roentgen of exposure will produce about 2 billion ion pairs per cubic centimeter of air. First introduced at the Radiological Congress held in Stockholm as the special unit for expressing exposure to ionizing radiation, it is now obsolete. See also *gray*; *rad*; *rem*; *sievert*.

second (sec) An SI unit of the duration of 9,192,631,770 periods of radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium-133 atom.

second foot A unit of flow equivalent to cubic feet per second.

second-foot day A unit of volume. One second-foot day is the discharge during a 24-hour period when the rate of flow is 1 second foot (i.e., 1 cubic foot per second). In ordinary hydraulic computations, 1 cubic foot per second flowing for 1 day is commonly taken as 2 acre-feet. The US Geological Survey now uses the term *cfs day* (cubic feet per second day) in its published reports.

section A unit of area in public land surveying. One section is a land area of 1 square mile.

SI See *Système International*.

siemens (S) An SI unit of the derived unit for electrical conductance, equivalent to seconds cubed amperes squared per meter squared per kilogram. One siemens is the electrical conductance of a conductor in which a current of 1 ampere is produced by an electric potential difference of 1 volt.

sievert (Sv) An SI unit of *equivalent* ionizing radiation dose. One sievert is the dose equivalent when the adsorbed dose of ionizing radiation multiplied by the dimensionless factors Q (quality factors) and N (product of any other multiplying factors) is 1 joule per kilogram. One sievert is equal to 100 rem. See also *gray*; *rad*; *rem*.

slug The base unit of mass. A slug is a mass that will accelerate at 1 foot per second squared when 1 pound force is applied.

square foot (ft²) A unit of area equivalent to that of a square, 1 foot on each side.

square inch (in.²) A unit of area equivalent to that of a square, 1 inch on each side.

square meter (m²) A unit of area equivalent to that of a square, 1 meter on each side.

square mile (mi²) A unit of area equivalent to that of a square, 1 mile on each side.

standard cubic feet per minute (SCFM) A unit for expressing the flow rate of air. This unit represents cubic feet of air per minute at standard conditions of temperature, pressure, and humidity (32° Fahrenheit, 14.7 pounds per square inch absolute, and 50% relative humidity).

steradian (sr) An SI unit of measure of a solid angle which, having its vertex in the center of a sphere, cuts off an area on the surface of the sphere equal to that of a square with sides of length equal to the radius of the sphere.

Système International (SI) The International System of Units of measure as defined by the periodic meeting of the General Conference on Weights and Measures. This system is sometimes called the international metric system or Le Système International d'Unités. The SI is a rationalized selection of units from the metric system with seven base units for which names, symbols, and precise definitions have been established. Many derived units are defined in terms of the base units, with symbols assigned to each and, in some cases, given names (e.g., the newton [N]). The great advantage of SI is its establishment of one and only one unit for each physical quantity—the meter for length, the kilogram (not the gram) for mass, the second for time, and so on. From these elemental units, units for all other mechanical quantities are derived. Another advantage is the ease with which unit conversions can be made, as few conversion factors need to be invoked.

tesla (T) An SI unit of magnetic flux density, equivalent to kilograms per second squared per ampere. One tesla is the magnetic flux density given by a magnetic flux of 1 weber per square meter.

ton A unit of force and mass defined as 2,000 pounds.

tonne (t) A unit of mass defined as 1,000 kilograms. A tonne is sometimes called a metric ton.

torr A unit of pressure. One torr is equal to 1 centimeter of mercury at 0° Celsius.

true color unit (tcu) A unit of color measurement based on the platinum–cobalt color unit. This unit is applied to water samples in which the turbidity has been removed. One true color unit equals 1 color unit. See also *color unit*.

turbidity unit See *nephelometric turbidity unit*.

US customary system of units A system of units based on the yard and the pound, commonly used in the United States and defined in “Unit of Weights and Measures (United States Customary and Metric): Definitions and Tables of Equivalents,” *National Bureau of Standards Miscellaneous Publication MP 233*, Dec. 20, 1960. Most of the units have a historical origin from the United Kingdom (e.g., the length of a king’s foot for the length of 1 foot; the area a team of horses could plow in a day—without getting tired—for an acre; the load a typical horse could lift in a minute for horsepower, and so forth). No organized method of multiples and fractions is involved. See also *Système International*.

volt (V) An SI unit of electrical potential, potential difference, and electromotive force, equivalent to meters squared kilograms per second cubed per ampere. One volt is the difference of electric potential between two points of a conductor, carrying a constant current of 1 ampere, when the power dissipated between these points is equal to 1 watt.

volt-ampere (VA) A unit used for expressing apparent power and complex power.

volt-ampere-reactive (VAR) A unit used for expressing reactive power.

watt (W) An SI unit of power and radiant flux, equivalent to meters squared kilograms per second cubed. One watt is the power that gives rise to the production of energy at the rate of 1 joule per second. Watts represent a measure of active power and instantaneous power.

weber (Wb) An SI unit of magnetic flux, equivalent to meters squared kilograms per second squared per ampere. One weber is the magnetic flux that, linking a circuit of one turn, produces in the circuit an electromotive force of 1 volt as the magnetic flux is reduced to zero at a uniform rate in 1 second.

yard (yd) A unit of length equal to 3 feet.

CONVERSION OF US CUSTOMARY UNITS

Linear Measurement

fathoms	× 6	= feet (ft)
feet (ft)	× 12	= inches (in.)
inches (in.)	× 0.0833	= feet (ft)
miles (mi)	× 5,280	= feet (ft)
yards (yd)	× 3	= feet (ft)
yards (yd)	× 36	= inches (in.)

Circular Measurement

degrees (angle)	× 60	= minutes (angle)
degrees (angle)	× 0.01745	= radians

Area Measurement

acres	× 43,560	= square feet (ft ²)
square feet (ft ²)	× 144	= square inches (in. ²)
square inches (in. ²)	× 0.00695	= square feet (ft ²)
square miles (mi ²)	× 640	= acres
square miles (mi ²)	× 27,878,400	= square feet (ft ²)
square miles (mi ²)	× 3,098,000	= square yards (yd ²)
square yards (yd ²)	× 9	= square feet (ft ²)

Volume Measurement

acre-feet (acre-ft)	× 43,560	= cubic feet (ft ³)
acre-feet (acre-ft)	× 325,851	= gallons (gal)
barrels petroleum (bo)	× 42	= gallons (gal)
board foot (fbm)		= 144 square inches × 1 inch
cubic feet (ft ³)	× 1,728	= cubic inches (in. ³)
cubic feet (ft ³)	× 7.48052	= gallons (gal)
cubic feet (ft ³)	× 29.92	= quarts (qt)
cubic feet (ft ³)	× 59.84	= pints (pt)
cubic feet (ft ³)	× 0.000023	= acre feet (acre-ft)
cubic inches (in. ³)	× 0.00433	= gallons (gal)
cubic inches (in. ³)	× 0.00058	= cubic feet (ft ³)
drops	× 60	= teaspoons (tsp)
gallons (gal)	× 0.1337	= cubic feet (ft ³)
gallons (gal)	× 231	= cubic inches (in. ³)
gallons (gal)	× 0.0238	= barrels petroleum (bo)
gallons (gal)	× 4	= quarts (qt)
gallons (gal)	× 8	= pints (pt)
gallons, US	× 0.83267	= gallons, Imperial



Documents

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gallons (gal)	× 0.00000308	= acre-feet (acre-ft)
gallons (gal)	× 0.0238	= barrels (petroleum) (bo)
gallons, Imperial	× 1.20095	= gallons, US
pints (pt)	× 2	= quarts (qt)
quarts (qt)	× 4	= gallons (gal)
quarts (qt)	× 57.75	= cubic inches (in. ³)

Pressure Measurement

atmospheres	× 29.92	= inches of mercury
atmospheres	× 33.90	= feet of water
atmospheres	× 14.70	= pounds per square inch (lb/in. ²)
feet of water	× 0.8826	= inches of mercury
feet of water	× 0.02950	= atmospheres
feet of water	× 0.4335	= pounds per square inch (lb/in. ²)
feet of water	× 62.43	= pounds per square foot (lb/ft ²)
feet of water	× 0.8876	= inches of mercury
inches of mercury	× 1.133	= feet of water
inches of mercury	× 0.03342	= atmospheres
inches of mercury	× 0.4912	= pounds per square inch (lb/in. ²)
inches of water	× 0.002458	= atmospheres
inches of water	× 0.07355	= inches of mercury
inches of water	× 0.03613	= pounds per square inch (lb/in. ²)
pounds/square in. (lb/in. ²)	× 144	= pounds per square foot (lb/ft ²)
pounds/square foot (lb/ft ²)	× .00694	= pounds per square inch (lb/in. ²)
pounds/square in. (lb/in. ²)	× 2.307	= feet of water
pounds/square inch (lb/in. ²)	× 2.036	= inches of mercury
pounds/square inch (lb/in. ²)	× 27.70	= inches of water

Weight Measurement

cubic feet of ice	× 57.2	= pounds (lb)
cubic feet of water (50°F)	× 62.4	= pounds of water
cubic inches of water	× 0.036	= pounds of water
gallons of water (50°F)	× 8.3453	= pounds of water
milligrams/liter (mg/L)	× 0.0584	= grains per gallon (US) (gpg)
milligrams/liter (mg/L)	× 0.07016	= grains per gallon (UK) (Imp)
milligrams/liter (mg/L)	× 8.345	= pounds per million gallons (lb/mil gal)
ounces (oz)	× 437.5	= grains (gr)

parts per million (ppm)	× 1	= milligrams per liter (mg/L) (for normal water applications)
grains per gallon (gpg)	× 17.118	= parts per million (ppm)
grains per gallon (gpg)	× 142.86	= pounds per million gallons (lb/mil gal)
percent solution	× 10,000	= milligrams per liter (mg/L)
pounds (lb)	× 16	= ounces (oz)
pounds (lb)	× 7,000	= grains (gr)
pounds (lb)	× 0.0005	= tons (short)
pounds/cubic inch (lb/in. ³)	× 1,728	= pounds per cubic foot (lb/ft ³)
pounds of water	× 0.0160	= cubic feet (ft ³)
pounds of water	× 27.68	= cubic inches (in. ³)
pounds of water	× 0.1198	= gallons (gal)
tons (short)	× 2,000	= pounds (lb)
tons (short)	× 0.89287	= tons (long)
tons (long)	× 2,240	= pounds (lb)
cubic feet air (at 60°F and 29.92 in. mercury)	× 0.0763	= pounds (lb)

Flow Measurement

barrels per hour petroleum (bo/hr)	× 0.70	= gallons per minute (gpm)
acre-feet/minute (acre-ft/min)	× 325,853	= gallons per minute (gpm)
acre-feet/minute (acre-ft/min)	× 726	= cubic feet per second (ft ³ /sec)
cubic feet/minute (ft ³ /min)	× 0.1247	= gallons per second (gps)
cubic feet/minute (ft ³ /min)	× 62.43	= pounds of water per minute
cubic feet/second (ft ³ /sec)	× 448.831	= gallons per minute (gpm)
cubic feet/second (ft ³ /sec)	× 0.646317	= million gallons per day (mgd)
cubic feet/second (ft ³ /sec)	× 1.984	= acre-feet per day (acre-ft/day)
gallons/minute (gpm)	× 1,440	= gallons per day (gpd)
gallons/minute (gpm)	× 0.00144	= million gallons per day (mgd)
gallons/minute (gpm)	× 0.00223	= cubic feet per second (ft ³ /sec)
gallons/minute (gpm)	× 0.1337	= cubic feet per minute (ft ³ /min)
gallons/minute (gpm)	× 8.0208	= cubic feet per hour (ft ³ /hr)
gallons/minute (gpm)	× 0.00442	= acre-feet per day (acre-ft/day)
gallons/minute (gpm)	× 1.43	= barrels (42 petroleum gal) per hour (bo/day)
gallons water/minute	× 6.0086	= tons of water per 24 hours
million gallons/day (mgd)	× 1.54723	= cubic feet per second (ft ³ /sec)
million gallons/day (mgd)	× 92.82	= cubic feet per minute (ft ³ /min)
million gallons/day (mgd)	× 694.4	= gallons per minute (gpm)
million gallons/day (mgd)	× 3.07	= acre-feet per day (acre-ft/day)
pounds of water/minute	× 0.000267	= cubic feet per second (ft ³ /sec)

Work Measurement

British thermal units (Btu)	× 778.2	= foot-pounds (ft-lb)
British thermal units (Btu)	× 0.000393	= horsepower-hours (hp·hr)
British thermal units (Btu)	× 0.000293	= kilowatt-hours (kW·hr)
foot-pounds (ft-lb)	× 0.001286	= British thermal units (Btu)
foot-pounds (ft-lb)	× 0.000000505	= horsepower-hours (hp·hr)
foot-pounds (ft-lb)	× 0.000000377	= kilowatt-hours (kW·hr)
horsepower-hours (hp·hr)	× 2,547	= British thermal units (Btu)
horsepower-hours (hp·hr)	× 0.7457	= kilowatt-hours (kW·hr)
kilowatt-hours (kW·hr)	× 3,412	= British thermal units (Btu)
kilowatt-hours (kW·hr)	× 1.341	= horsepower-hours (hp·hr)

Power Measurement

boiler horsepower	× 33,480	= British thermal units per hour (Btu/hr)
boiler horsepower	× 9.8	= kilowatts (kW)
British thermal units/second (Btu/sec)	× 1.0551	= kilowatts (kW)
British thermal units/minute (Btu/min)	× 12.96	= foot-pounds per second (ft-lb/sec)
British thermal units/minute (Btu/min)	× 0.02356	= horsepower (hp)
British thermal units/minute (Btu/min)	× 0.01757	= kilowatts (kW)
British thermal units/hour (Btu/hr)	× 0.293	= watts (W)
British thermal units/hour (Btu/hr)	× 12.96	= foot-pounds per minute (ft-lb/min)
British thermal units/hour (Btu/hr)	× 0.00039	= horsepower (hp)
foot-pounds per second (ft-lb/sec)	× .0771	= British thermal units per minute (Btu/min)
foot-pounds per second (ft-lb/sec)	× .001818	= horsepower (hp)
foot-pounds per second (ft-lb/sec)	× .001356	= kilowatts (kW)
foot-pounds per minute (ft-lb/min)	× .0000303	= horsepower (hp)
foot-pounds per minute (ft-lb/min)	× .0000226	= kilowatts (kW)
horsepower (hp)	× 42.44	= British thermal units per minute (Btu/min)

horsepower (hp)	× 33,000	= foot-pounds per minute (ft-lb/min)
horsepower (hp)	× 550	= foot-pounds per second (ft-lb/sec)
horsepower (hp)	× 1,980,000	= foot-pounds per hour (ft-lb/hr)
horsepower (hp)	× 0.7457	= kilowatts (kW)
horsepower (hp)	× 745.7	= watts (W)
kilowatts (kW)	× 0.9478	= British thermal units per second (Btu/sec)
kilowatts (kW)	× 56.87	= British thermal units per minute (Btu/min)
kilowatts (kW)	× 3,413	= British thermal units per hour (Btu/hr)
kilowatts (kW)	× 44,250	= foot-pounds per minute (ft-lb/min)
kilowatts (kW)	× 737.6	= foot-pounds per second (ft-lb/sec)
kilowatts (kW)	× 1.341	= horsepower (hp)
tons of refrigeration (US)	× 288,000	= British thermal units per 24 hours
watts (W)	× 0.05692	= British thermal units per minute (Btu/min)
watts (W)	× 0.7376	= foot-pounds (force) per second (ft-lb/sec)
watts (W)	× 44.26	= foot-pounds per minute (ft-lb/min)
watts (W)	× 0.001341	= horsepower (hp)

Velocity Measurement

feet/minute (ft/min)	× 0.01667	= feet per second (ft/sec)
feet/minute (ft/min)	× 0.01136	= miles per hour (mph)
feet/second (ft/sec)	× 0.6818	= miles per hour (mph)
miles/hour (mph)	× 88	= feet per minute (ft/min)
miles/hour (mph)	× 1.467	= feet per second (ft/sec)

Miscellaneous

grade: 1 percent (or 0.01)	= 1 foot per 100 feet
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CONVERSION OF METRIC UNITS

Linear Measurement

inch (in.)	× 25.4	= millimeters (mm)
inch (in.)	× 2.54	= centimeters (cm)
foot (ft)	× 304.8	= millimeters (mm)
foot (ft)	× 30.48	= centimeters (cm)
foot (ft)	× 0.3048	= meters (m)
yard (yd)	× 0.9144	= meters (m)
mile (mi)	× 1,609.3	= meters (m)
mile (mi)	× 1.6093	= kilometers (km)
millimeter (mm)	× 0.03937	= inches (in.)
centimeter (cm)	× 0.3937	= inches (in.)
meter (m)	× 39.3701	= inches (in.)
meter (m)	× 3.2808	= feet (ft)
meter (m)	× 1.0936	= yards (yd)
kilometer (km)	× 0.6214	= miles (mi)

Area Measurement

square meter (m ²)	× 10,000	= square centimeters (cm ²)
hectare (ha)	× 10,000	= square meters (m ²)
square inch (in. ²)	× 6.4516	= square centimeters (cm ²)
square foot (ft ²)	× 0.092903	= square meters (m ²)
square yard (yd ²)	× 0.8361	= square meters (m ²)
acre	× 0.004047	= square kilometers (km ²)
acre	× 0.4047	= hectares (ha)
square mile (mi ²)	× 2.59	= square kilometers (km ²)
square centimeter (cm ²)	× 0.16	= square inches (in. ²)
square meters (m ²)	× 10.7639	= square feet (ft ²)
square meters (m ²)	× 1.1960	= square yards (yd ²)
hectare (ha)	× 2.471	= acres
square kilometer (km ²)	× 247.1054	= acres
square kilometer (km ²)	× 0.3861	= square miles (mi ²)

Volume Measurement

cubic inch (in. ³)	× 16.3871	= cubic centimeters (cm ³)
cubic foot (ft ³)	× 28,317	= cubic centimeters (cm ³)
cubic foot (ft ³)	× 0.028317	= cubic meters (m ³)
cubic foot (ft ³)	× 28.317	= liters (L)
cubic yard (yd ³)	× 0.7646	= cubic meters (m ³)
acre foot (acre-ft)	× 1,233.4	= cubic meters (m ³)



ounce (US fluid) (oz)	× 0.029573	= liters (L)
quart (liquid) (qt)	× 946.9	= milliliters (mL)
quart (liquid) (qt)	× 0.9463	= liters (L)
gallon (gal)	× 3.7854	= liters (L)
gallon (gal)	× 0.0037854	= cubic meters (m ³)
peck (pk)	× 0.881	= decaliters (dL)
bushel (bu)	× 0.3524	= hectoliters (hL)
cubic centimeters (cm ³)	× 0.061	= cubic inches (in. ³)
cubic meter (m ³)	× 35.3183	= cubic feet (ft ³)
cubic meter (m ³)	× 1.3079	= cubic yards (yd ³)
cubic meter (m ³)	× 264.2	= gallons (gal)
cubic meter (m ³)	× 0.000811	= acre-feet (acre-ft)
liter (L)	× 1.0567	= quart (liquid) (qt)
liter (L)	× 0.264	= gallons (gal)
liter (L)	× 0.0353	= cubic feet (ft ³)
decaliter (dL)	× 2.6417	= gallons (gal)
decaliter (dL)	× 1.135	= pecks (pk)
hectoliter (hL)	× 3.531	= cubic feet (ft ³)
hectoliter (hL)	× 2.84	= bushels (bu)
hectoliter (hL)	× 0.131	= cubic yards (yd ³)
hectoliter (hL)	× 26.42	= gallons (gal)

Pressure Measurement

pound/square inch (psi)	× 6.8948	= kilopascals (kPa)
pound/square inch (psi)	× 6,894	= pascals (Pa)
pound/square inch (psi)	× 0.070307	= kilograms/square centimeter (kg/cm ²)
pound/square foot (lb/ft ²)	× 47.8803	= pascals (Pa)
pound/square foot (lb/ft ²)	× 0.000488	= kilograms/square centimeter (kg/cm ²)
pound/square foot (lb/ft ²)	× 4.8824	= kilograms/square meter (kg/m ²)
inches of mercury	× 3,386.4	= pascals (Pa)
inches of water	× 248.84	= pascals (Pa)
bar	× 100,000	= newtons per square meter (N/m ²)
pascals (Pa)	× 1	= newtons per square meter (N/m ²)
pascals (Pa)	× 0.000145	= pounds/square inch (psi)
kilopascals (kPa)	× 0.145	= pounds/square inch (psi)
pascals (Pa)	× 0.000296	= inches of mercury (at 60°F)

kilogram/square centimeter $\times$ 14.22 (kg/cm ²)	= pounds/square inch (psi)
kilogram/square centimeter $\times$ 28.959 (kg/cm ²)	= inches of mercury (at 60°F)
kilogram/square meter $\times$ 0.2048 (kg/m ²)	= pounds per square foot (lb/ft ²)
centimeters of mercury $\times$ 0.4461	= feet of water

Weight Measurement

ounce (oz) $\times$ 28.3495	= grams (g)
pound (lb) $\times$ 453.59	= grams (g)
pound (lb) $\times$ 0.4536	= kilograms (kg)
ton (short) $\times$ 0.9072	= megagrams (metric ton)
pounds/cubic foot (lb/ft ³) $\times$ 16.02	= grams per liter (g/L)
pounds/million gallons $\times$ 0.1198 (lb/mil gal)	= grams per cubic meter (g/m ³)
gram (g) $\times$ 15.4324	= grains (gr)
gram (g) $\times$ 0.0353	= ounces (oz)
gram (g) $\times$ 0.0022	= pounds (lb)
kilograms (kg) $\times$ 2.2046	= pounds (lb)
kilograms (kg) $\times$ 0.0011	= tons (short)
megagram (metric ton) $\times$ 1.1023	= tons (short)
grams/liter (g/L) $\times$ 0.0624	= pounds per cubic foot (lb/ft ³)
grams/cubic meter (g/m ³) $\times$ 8.3454	= pounds/million gallons (lb/mil gal)

Flow Measurement

gallons/second (gps) $\times$ 3.785	= liters per second (L/sec)
gallons/minute (gpm) $\times$ 0.00006308	= cubic meters per second (m ³ /sec)
gallons/minute (gpm) $\times$ 0.06308	= liters per second (L/sec)
gallons/hour (gph) $\times$ 0.003785	= cubic meters per hour (m ³ /hr)
gallons/day (gpd) $\times$ 0.000003785	= million liters per day (ML/day)
gallons/day (gpd) $\times$ 0.003785	= cubic meters per day (m ³ /day)
cubic feet/second (ft ³ /sec) $\times$ 0.028317	= cubic meters per second (m ³ /sec)
cubic feet/second (ft ³ /sec) $\times$ 1,699	= liters per minute (L/min)
cubic feet/minute (ft ³ /min) $\times$ 472	= cubic centimeters/second (cm ³ /sec)
cubic feet/minute (ft ³ /min) $\times$ 0.472	= liters per second (L/sec)
cubic feet/minute (ft ³ /min) $\times$ 1.6990	= cubic meters per hour (m ³ /hr)
million gallons/day (mgd) $\times$ 43.8126	= liters per second (L/sec)

million gallons/day (mgd)	$\times 3,785$	= cubic meters per day (m^3/day)
million gallons/day (mgd)	$\times 0.043813$	= cubic meters per second (m^3/sec)
gallons/square foot (gal/ft^2)	$\times 40.74$	= liters per square meter (L/m^2)
gallons/acre/day ($\text{gal}/\text{acre}/\text{day}$)	$\times 0.0094$	= cubic meters/hectare/day ($\text{m}^3/\text{ha}/\text{day}$)
gallons/square foot/day ($\text{gal}/\text{ft}^2/\text{day}$)	$\times 0.0407$	= cubic meters/square meter/day ($\text{m}^3/\text{m}^2/\text{day}$)
gallons/square foot/day ($\text{gal}/\text{ft}^2/\text{day}$)	$\times 0.0283$	= liters/square meter/min ($\text{L}/\text{m}^2/\text{m}$)
gallons/square foot/minute ($\text{gal}/\text{ft}^2/\text{min}$)	$\times 2.444$	= cubic meters/square meter/hour ($\text{m}^3/\text{m}^2/\text{hr}$) = m/hr
gallons/square foot/minute ($\text{gal}/\text{ft}^2/\text{min}$)	$\times 0.679$	= liters/square meter/second ($\text{L}/\text{m}^2/\text{sec}$)
gallons/square foot/minute ($\text{gal}/\text{ft}^2/\text{min}$)	$\times 40.7458$	= liters/square meter/minute ($\text{L}/\text{m}^2/\text{min}$)
gallons/capita/day (gpcd)	$\times 3.785$	= liters/day/capita ($\text{L}/\text{d}/\text{capita}$)
liters/second (L/sec)	$\times 22,824.5$	= gallons per day (gpd)
liters/second (L/sec)	$\times 0.0228$	= million gallons per day (mgd)
liters/second (L/sec)	$\times 15.8508$	= gallons per minute (gpm)
liters/second (L/sec)	$\times 2.119$	= cubic feet per minute (ft^3/min)
liters/minute (L/min)	$\times 0.0005886$	= cubic feet per second (ft^3/sec)
cubic centimeters/second (cm^3/sec)	$\times 0.0021$	= cubic feet per minute (ft^3/min)
cubic meters/second (m^3/sec)	$\times 35.3147$	= cubic feet per second (ft^3/sec)
cubic meters/second (m^3/sec)	$\times 22.8245$	= million gallons per day (mgd)
cubic meters/second (m^3/sec)	$\times 15,850.3$	= gallons per minute (gpm)
cubic meters/hour (m^3/hr)	$\times 0.5886$	= cubic feet per minute (ft^3/min)
cubic meters/hour (m^3/hr)	$\times 4.403$	= gallons per minute (gpm)
cubic meters/day (m^3/day)	$\times 264.1720$	= gallons per day (gpd)
cubic meters/day (m^3/day)	$\times 0.00026417$	= million gallons per day (mgd)
cubic meters/hectare/day ($\text{m}^3/\text{ha}/\text{day}$)	$\times 106.9064$	= gallons per acre per day ($\text{gal}/\text{acre}/\text{day}$)
cubic meters/square meter/day ($\text{m}^3/\text{m}^2/\text{day}$)	$\times 24.5424$	= gallons/square foot/day ($\text{gal}/\text{ft}^2/\text{day}$)
liters/square meter/minute ($\text{L}/\text{m}^2/\text{min}$)	$\times 0.0245$	= gallons/square foot/minute ($\text{gal}/\text{ft}^2/\text{min}$)
liters/square meter/minute ($\text{L}/\text{m}^2/\text{min}$)	$\times 35.3420$	= gallons/square foot/day ($\text{gal}/\text{ft}^2/\text{day}$)

Work, Heat, and Energy Measurements

British thermal units (Btu)	$\times 1.0551$	= kilojoules (kJ)
British thermal units (Btu)	$\times 0.2520$	= kilogram-calories (kg-cal)
foot-pound (force) (ft-lb)	$\times 1.3558$	= joules (J)
horsepower-hour (hp · hr)	$\times 2.6845$	= megajoules (MJ)
watt-second (W-sec)	$\times 1.000$	= joules (J)
watt-hour (W · hr)	$\times 3.600$	= kilojoules (kJ)
kilowatt-hour (kW · hr)	$\times 3,600$	= kilojoules (kJ)
kilowatt-hour (kW · hr)	$\times 3,600,000$	= joules (J)
British thermal units per pound (Btu/lb)	$\times 0.5555$	= kilogram-calories per kilogram (kg-cal/kg)
British thermal units per cubic foot (Btu/ft ³)	$\times 8.8987$	= kilogram-calories/cubic meter (kg-cal/m ³)
kilojoule (kJ)	$\times 0.9478$	= British thermal units (Btu)
kilojoule (kJ)	$\times 0.00027778$	= kilowatt-hours (kW · hr)
kilojoule (kJ)	$\times 0.2778$	= watt-hours (W · hr)
joule (J)	$\times 0.7376$	= foot-pounds (ft-lb)
joule (J)	$\times 1.0000$	= watt-seconds (W-sec)
joule (J)	$\times 0.2399$	= calories (cal)
megajoule (MJ)	$\times 0.3725$	= horsepower-hour (hp · hr)
kilogram-calories (kg-cal)	$\times 3.9685$	= British thermal units (Btu)
kilogram-calories per kilogram (kg-cal/kg)	$\times 1.8000$	= British thermal units per pound (Btu/lb)
kilogram-calories per liter (kg-cal/L)	$\times 112.37$	= British thermal units per cubic foot (Btu/ft ³)
kilogram-calories/cubic meter (kg-cal/m ³)	$\times 0.1124$	= British thermal units per cubic foot (Btu/ft ³)

Velocity, Acceleration, and Force Measurements

feet per minute (ft/min)	$\times 18.2880$	= meters per hour (m/hr)
feet per hour (ft/hr)	$\times 0.3048$	= meters per hour (m/hr)
miles per hour (mph)	$\times 44.7$	= centimeters per second (cm/sec)
miles per hour (mph)	$\times 26.82$	= meters per minute (m/min)
miles per hour (mph)	$\times 1.609$	= kilometers per hour (km/hr)
feet/second/second (ft/sec ²)	$\times 0.3048$	= meters/second/second (m/sec ²)
inches/second/second (in./sec ²)	$\times 0.0254$	= meters/second/second (m/sec ²)
pound-force (lbf)	$\times 4.44482$	= newtons (N)
centimeters/second (cm/sec)	$\times 0.0224$	= miles per hour (mph)



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meters/second (m/sec)	× 3.2808	= feet per second (ft/sec)
meters/minute (m/min)	× 0.0373	= miles per hour (mph)
meters per hour (m/hr)	× 0.0547	= feet per minute (ft/min)
meters per hour (m/hr)	× 3.2808	= feet per hour (ft/hr)
kilometers/second (km/sec)	× 2,236.9	= miles per hour (mph)
kilometers/hour (km/hr)	× 0.0103	= miles per min (mpm)
meters/second/second (m/sec ²)	× 3.2808	= feet/second/second (ft/sec ²)
meters/second/second (m/sec ²)	× 39.3701	= inches/second/second (in./sec ²)
newtons (N)	× 0.2248	= pounds force (lbf)

Factors for Conversion

US	Multiply by	Metric (SI) or US
Length		
inches (in.)	2.540	centimeters (cm)
	0.0254	meters (m)
feet (ft)	0.3048	meter (m)
	12	inches (in.)
yard (yd)	0.9144	meters (m)
	3	feet (ft)
miles (mi)	1.609	kilometers (km)
	1,760	yards (yd)
	5,280	feet (ft)
Area		
square inch (in. ²)	6.452	square centimeters (cm ²)
square feet (ft ²)	0.0929	square meters (m ²)
	144	square inches (in. ²)
	4,047	square meters (m ²)
acres	0.4047	hectares (ha)
	43,560	square feet (ft ²)
	0.001562	square miles (mi ²)
square miles (mi ²)	2.590	square kilometers (km ²)
	640	acres
Volume		
cubic feet (ft ³)	28.32	liters (L)
	0.02832	cubic meters (m ³)
	7.48	gallons, US
	6.23	gallons, Imperial
cubic yard (yd ³)	1,728	cubic inches (in. ³)
	0.7646	cubic meters (m ³)
	3.785	liters (L)
gallon (gal)	0.003785	cubic meters (m ³)
	4	quarts (qt)
	8	pints (pt)
	128	fluid ounces (fl oz)
	0.1337	cubic feet (ft ³)

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